The appended titles are those of a few only of the works and papers that might be cited in this connection:

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——— "Pre-Columbian Syphilis in the Western Hemisphere," Cincinnati Lancet-Clinic, March 8, 1890.

Fournier, A.: "Syphilis Héréditaire Tardive," Paris, 1886.

Jones, Joseph: "Explorations of the Aboriginal Remains of Tennessee," Smithsonian Institution, Washington, 1876.

——— "Explorations and Researches concerning the Destruction of the Aboriginal Inhabitants of America," New Orleans Medical and Surgical Journal, June, 1878.

Lancereaux: "Traité de la Syphilis," Paris, 1873.

Langdon, F. W.: "The Madisonville Prehistoric Cemetery" [Author's edition], Journal of Cincinnati Society of Natural History, October, 1881.

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Taylor, R. W.: "Syphilitic Lesions of the Osseous System in Infants and Young Children," New York, 1875.

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NITROGEN MONOXIDE AND OXYGEN FOR ANÆSTHESIA IN MINOR SURGICAL OPERATIONS.

WITH A REPORT OF FIFTY CASES.[1]

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IN some physiological text-books we are told that mixtures of nitrous oxide and oxygen gas may be inhaled with impunity for any length of time, and when thus inhaled produce anæsthesia without unconsciousness. If this were true we would have in such mixtures the ideal anæsthetic that has for so long a time been the dream of many surgeons. A perfectly safe anæsthetic, respirable for hours by the patient, which would never fail to produce complete anæsthesia during any operation, and yet not render the patient unconscious, would be hailed as an advance in surgery.

In a recent paper read before the International Congress at Berlin, Horatio C. Wood spoke of such a "perfect anæsthetic," but added: "If such a drug exists (which has the power of paralyzing the sensory nerve-trunks without affecting other functions of the body) it yet awaits the coming of its discoverer."

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[1] Read before the New York Surgical Society, with a demonstration on a patient of the method employed, Dec. 10, 1890.

Unfortunately, the above assertion in regard to the mixtures of nitrogen monoxide and oxygen requires considerable modification before it can be experimentally and clinically verified. If, however, there has been some advance toward finding the ideal anæsthetic referred to, this advance has been achieved by means of experiments conducted with such mixtures.

The use of pure nitrogen monoxide, so serviceable and efficient in dental practice as an anæsthetic, is not entirely so in surgery, even for minor operative procedures. It is true, for such operations as are of the very shortest possible duration, such as the incision into an abscess, it is a very valuable aid to their satisfactory performance, and one which we can ill afford to do without, whenever we have so great a number of such operations to perform that the question as to the amount of time spent on each one becomes an important one—as is the case in our public dispensaries.

But the short space of time during which complete anæsthesia, with loss of all reflexes, can be maintained by the administration of pure nitrogen monoxide interferes with the proper circumspect performance of the majority of operations generally classed together as minor operations (which we are called upon to perform in our clinics and dispensaries), especially when we make extensive use of the antiseptic method.

The opening and drainage, with incidental irrigation, of a palmar abscess, the cleansing and suture of an incised wound, the treatment of an abscess of the mammary gland, or of an acute suppurative lymphadenitis of the neck, cannot be satisfactorily conducted with the administration of pure nitrogen monoxide. I have myself used this anæsthetic in some 400 cases of the kind above described, and have always been oppressed by the sense of having to use undue haste in the performance of these small procedures.

But when such minor operations as the extirpation of ingrowing toenails, or the removal of cystic tumors of the scalp were to be performed, the administration of nitrogen monoxide in its pure form proved totally unsatisfactory and could not in any way compete with the use of cocaine.

Pure nitrogen monoxide, if given continuously, will produce complete anæsthesia with unconsciousness, on the average, in two minutes and eight seconds; and total cessation of respiration in about three minutes, on the average, which means death by asphyxia unless oxygen is speedily supplied. It is the deep cyanosis of the skin, and the dark-blue color of the blood flowing from the wound that induces the surgeon to abandon the anæsthetic before death ensues, and this, together with the fact that the heart continues to beat after respiration has ceased, constitutes the comparative safety of this anæsthetic—a safety which, however, exists only at the expense of the oftentimes unsatisfactory completion of the operation. The clonic spasms which occur before death are also liable to displace the mask and thus admit air into the lungs.

Although in many cases death may not occur so soon, in others it has occurred as early as after two minutes' inhalation of nitrogen monoxide. I recall only two cases where, before even the incision of an abscess could be accomplished, a state of asphyxia had obtained which was the cause, for some moments, of considerable anxiety on the part of the surgeon before the patients finally recovered. Both cases occurred in children, who generally take nitrogen monoxide very well.[1]

The physiological action of the nitrogen monoxide is now generally admitted to consist in shutting off oxygen from the blood. This action is not to be confounded with simple asphyxia after mechanical occlusion of the air-passages; because in this latter case there is carbon dioxide present in the blood, which acts as a poison.

In asphyxia occurring after administration of pure nitrogen monoxide, there is simply a lack of oxygen in the tissues.

It is true, Ulbrich asserted that spectroscopic analysis of blood saturated with nitrogen monoxide showed no hæmoglobin to be present. But latterly Rothmann, by using more diluted solutions of such blood, established the presence of the hæmoglobin spectrum unimpaired, so that it must be conceded that there is no chemical action of the nitrogen monoxide upon the blood other than the simple shutting off of oxygen.

If, therefore, there is any interference with bodily functions in consequence of the inhalation of pure nitrogen monoxide, this may be due either to the specific action of the nitrogen monoxide (which is probably the cause of anæsthesia, as the experiments done with mixtures show), or it may be due to the absence of oxygen; and this latter condition is probably the cause of the changes in the pulse and respiration, in the blood-pressure, and of the clonic spasms and tonic muscular contractions, observed after inhalation of nitrogen monoxide.

The action of the gas on the pulse and respiration has been described in a paper recently read before the National Academy of Medicine by Wood and Cerna, who found the pulse-rate decidedly slowed, while the arterial wave was enormously increased in size (due to stimulation of the inhibitory cardiac apparatus). The blood-pressure is extraordinarily raised, sometimes only momentarily and abruptly, and at various stages during the anæsthesia; but present in the majority of cases.

The respiration very soon fails, and ceases entirely at a time when the heart is yet in full action.

When viewed as an anæsthetic to be admitted into general surgical practice it is evident that nitrogen monoxide in its pure state may never aspire to that position of usefulness occupied by ether and chloroform.

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[1] From a verbal communication on the part of my colleague, Dr. Swinburne, I learn that he has observed four such cases, also occurring in children, in which considerable momentary apprehension was caused from an overdose of pure nitrogen monoxide, but in which perfect recovery followed.

In the first place the danger attendant upon its administration for a longer period of time than three minutes, on the average, renders its use unsatisfactory.

Secondly, the action on the pulse at the commencement of the anæsthesia, and the increased blood-pressure, are serious drawbacks and a positive contra-indication to its use in a number of cases.

If anæsthesia, once induced with pure nitrogen monoxide, is to be maintained for any considerable length of time, this can be only achieved by admitting air in greater or smaller quantities into the lungs of the patient, by which means the occurrence of complete asphyxia may be repeatedly postponed.

This method has been in extensive use for some time. The administrator watches the skin of the patient, and when cyanosis becomes so deep that a further increase of the asphyxia appears alarming, sufficient air is admitted to postpone, for a time, the complete arrest of respiration. Or a certain quantity of air may be admitted, intentionally or unintentionally, along with the nitrogen monoxide from the first. It depends upon the skill of the administrator to keep the patient between the two evils of complete cessation of respiration and the awakening to consciousness with the return of the reflex motions and struggling.

With great skill and experience on the part of the operator, however, a prolonged narcosis can be maintained, presenting much the same effect as chloroform anæsthesia, and there are in the literature a number of such cases where anæsthesia was maintained for an hour and more.

But in all these cases cyanosis was continued and pronounced, and the blood that flowed from the wound was of very dark color.

When we consider that this cyanosis is actually due to the want of oxygen, and that we have to deal with a condition of incomplete asphyxia continued for a long period of time, it appears questionable whether its effects may not result from this practice. There is a state of asphyxia of the tissues, which leads to inflammatory changes with subsequent degeneration.

An Esmarch bandage applied to the limb of an animal will, by shutting off the oxygen supply of the blood, produce such great molecular changes in the muscles (disappearance of the nuclei and inflammatory conditions) that they can be seen and studied with the microscope, as Leser has shown. And this occurs after three hours' application of the bandage. It is, therefore, not out of place to question whether such tissue-asphyxia may not be induced quite as readily by prolonged narcosis by mixtures of nitrogen monoxide and air.

Another point may here be mentioned. When only a little air is admitted along with the nitrogen monoxide, as soon as this air has entered into the lungs carbon dioxide appears in the blood. So that these patients present the same conditions as do patients suffering from simple mechanical asphyxia. Now, we know when patients pass from asphyxia produced by carbon dioxide poisoning to complete suffocation, they do so without muscular spasms or convulsions. We see, therefore, that although the anæsthesia with mixtures of air and nitrogen monoxide may keep the patient more quiet as to muscular reaction, it does so at no small detriment to the system. Indeed, I much question whether the sugar found in the urine after prolonged anæsthesia with nitrogen monoxide is not the expression of such detriment to the system.

Still another disadvantage may be here considered, which often attaches to these narcoses maintained by the admittance of air with the nitrogen monoxide, and that is the subjective sense of strangulation on the part of the patient. This sense is not always pronounced, however, and does not usually interfere with the performance of the operation.

In view of all these disadvantages attaching to the administration of nitrogen monoxide, either in its pure state or when mixed with air, it is not strange that many attempts should have been made to obtain all the benefits of such an agreeable and safe anæsthetic as nitrogen monoxide has the reputation of being, without its drawbacks and disadvantages.

One of the most evident methods of avoiding the danger lying in the asphyxiated condition resulting from inhalation of the nitrogen monoxide is the admixture of pure oxygen with the gas. This method has been repeatedly tried and again abandoned, so that surgeons in general had lost all hope of practically introducing it into general use.

According to Von Bruns, Hermann was the first to mix the gases, taking seventy-eight parts of nitrogen monoxide and twenty-two parts of oxygen, thus imitating our own atmosphere in the quantity of oxygen. He found that this mixture produced anæsthesia without loss of consciousness. Subsequently Von Bruns tried this mixture for surgical purposes, but was unsuccessful.

The most distinguished effort in this direction was made by Paul Bert in 1878.

His method of reasoning was simple: Pure nitrous monoxide causes anæsthesia at atmospheric pressure, but also asphyxia. The latter can be obviated by the admixture of as much oxygen as is contained in our atmosphere—*i. e.*, one volume of oxygen added to four volumes of the nitrogen monoxide. If, however, this admixture is made, the tension of the nitrogen monoxide in the mixture is not as great (by one-fifth) as it was before the admixture, and consequently no anæsthesia will be produced. In order to remedy this it is only necessary to increase the atmospheric pressure by just so much as the tension of the nitrogen monoxide gas is weakened by the addition of oxygen, namely, by one-fifth atmosphere. If this be done the result of inhalation will be anæsthesia without asphyxia.

The practical problem presenting itself for solution was how to obtain the atmospheric super-pressure. It was solved by Paul Bert by building a hermetically sealed glass cage with proper arrangements attached for increasing the atmospheric pressure. Into this cage the patient and the surgeons and assistants were all admitted, and here the gas was administered.

The practical obstacles in the way of this method are the expense of the apparatus, which alone amounted to 10,000 francs, and the difficulty of its transportation.

With this arrangement, however, success was manifest. A large number of operations were performed by L'Abbé and Péan, and the following observations were made:

With an admixture of 20 per cent. in volume of pure oxygen to the pure nitrogen monoxide, anæsthesia was almost instantly induced as soon as the patient commenced inhaling it. It could be continued for any desirable length of time. When inhalation was interrupted the patient instantly recovered. After anæsthesia no headache, no nausea, no digestive disturbance, was observed. No vomiting occurred. In short, the compound appeared perfectly safe and innocuous.

We have here an ideal anæsthetic for surgical use, but the practical difficulties in the way of its general introduction are insurmountable.

In the second year following, Raphael Blanchard published a monograph in which sixty operations of a major and minor character, some of over one hour's duration, were reported, all done after the same method of Paul Bert, and confirming his conclusions.

One year later, in 1881, Klikovitch, of St. Petersburg, began further experiments with a mixture similar to that used by Paul Bert in obstetrical practice and during parturition. He came to the conclusion that, for the purpose of rendering parturition painless, the inhalation of the mixture without additional pressure was sufficient. The patients retained their consciousness, although it was generally somewhat dulled.

The anæsthesia was not complete, however, the pain being merely diminished in some cases and not entirely removed.

The conclusions of Klikovitch were: (*a*) that the mixture was entirely free from danger for the mother and the child; (*b*) that pain was undoubtedly diminished; (*c*) that consciousness was not interfered with; (*d*) that no vomiting or intestinal disturbance was induced; (*e*) that no cumulative action of the gas mixture could be observed; (*f*) and that the mixture could be administered even without the presence of a physician; (*g*) but that the apparatus was not readily transportable and that the procedure was too expensive.

These observations were corroborated by Tittel, of Dresden, and by

E. Cohn, of Berlin, and I may add that we have two further contributions to the literature regarding the use of the mixture during labor. The one by Swiecicki, who writes in favor of its use, and the other by Doederlein, who was not so favorably impressed by it. An attempted incision of an abscess of the mammary gland was a failure as far as the anæsthesia was concerned. Both used a compound consisting of 20 per cent. of oxygen and 80 per cent. of nitrogen monoxide, without atmospheric super-pressure.

The first successful major surgical operation with a less cumbersome apparatus than that of Paul Bert, appears to be one published in 1888 by Witzinger.

A mixture was administered composed of twelve volumetric parts of oxygen and eighty-eight of nitrogen monoxide and continued for eighteen minutes, during which time Von Mosetig-Moorhof performed a resection of the hip-joint. The operation had not been completed when the supply of the mixture gave out and chloroform had to be substituted. In another operative case, however, also of a major character, but occurring in dispensary practice, the compound failed entirely; while in two minor operative procedures the anæsthetic was administered with success.

In these cases the gas compound was not administered under pressure; but the percentage of oxygen was reduced from that employed by Paul Bert.

The clinical observations made during the operation of hip-joint resection were as follows: Narcosis was complete after one minute and two seconds. There was no preliminary stage of excitation. Respiration was calm; the pupils were dilated; there was total absence of muscular tonus. The conjunctival reflex was abolished. The action of the heart was regular and strong.

In the following year, 1889, Gersuny, of Vienna, published eight cases of surgical operations in which Hillischer administered a mixture of twelve parts of oxygen and eighty-eight parts of nitrogen monoxide. The gases were mixed immediately before inspiration by means of a specially arranged stopcock. In six of these cases the narcosis was maintained for from eight and a half to fourteen minutes. In two of them the duration was thirty-three and thirty-eight minutes respectively. The time necessary to induce anæsthesia varied between one and a half and ten minutes. In two cases asphyxia occurred, and the operation was interrupted. Two cases were complicated by vomiting. The pulse was full, between 120 and 140; the blood-pressure sank during narcosis. Respiration was 50, with marked cyanosis in two of the cases. No evil after-effects were noticed.

These few operations are the only surgical procedures I have been able to find recorded in the literature, where use was made of mixtures of oxygen and nitrogen monoxide.

The other cases refer either to experiments done upon animals, or else to the use of the mixture in dental practice. Both of these categories interest us here only in so far as our knowledge of the physiological action of the mixture has been increased by them.

The most prominent among the more recent experiments upon animals published are those done by Wood and Cerna.

They found that the blood-pressure was not raised when a mixture of nitrogen monoxide and oxygen, containing 10 per cent. of the latter, was administered; but that the pulse-rate was reduced, just as in the administration of pure nitrogen monoxide. They also found, however, that such a mixture failed to produce anæsthesia.[1]

As regards the length of time during which the anæsthetic may be administered, Martin, in 1888, narcotized a dog with a mixture of fifteen parts of oxygen and eighty-five parts of nitrogen monoxide, and kept the animal continually under its influence for seventy-two consecutive hours. The dog slept peacefully all the time.

When a similar mixture (12½ parts of oxygen and 87½ parts of nitrogen monoxide) has been used on the human subject in dental practice for the purpose of painless extraction of teeth, it has been customary to mix the gases in a gasometer, and from these gasometers the mixtures generally escaped under slight pressure. A large number of such cases have been reported by Hewitt. In these cases, after a few inspirations, a slowing of the respiration was observed, but neither cyanosis nor stertorous breathing ever occurred. The pulse was full, strong, regular, between 80 and 90. These administrations were generally given for about two minutes; sensibility was sufficiently blunted to permit satisfactory work in extracting a tooth; muscular rigidity was sometimes present, and in some cases the anæsthetic failed completely.

In attempting to sum up the information given in all these data, and in the rest of the literature not quoted here pertaining to the mixtures, we are struck by the conflicting statements of different observers. The one statement, on which all appear agreed, is that the admixture of oxygen to the nitrogen monoxide does not cause an increase of the blood-pressure (Hillischer, 1866). The statements as to pulse and respiration vary. Asphyxia did not occur when the gases were previously mixed. But frequently the anæsthesia failed entirely, and often it was unsatisfactory; so that, with the exception of Paul Bert's cumbersome apparatus, surgical practice has as yet not profited much by these observations.

We may refer the lack of unity in the clinical observations made—to the variations in the methods and apparatus employed by the various administrators.

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[1] I learn from personal communication that Dr. B. F. Curtis, of this city, has lately performed similar experiments; but they have not yet been published, to my knowledge.

I now turn to my own experience with the mixtures of oxygen and nitrogen monoxide.

My attention was first called to these mixtures by my colleague, Dr. Moskovich, an expert in nitrous oxide anæsthesia and lecturer in the New York College of Dentistry, who told me, in June, 1889, of the experiments being made at that time in Russia.

I am indebted to the courtesy of Dr. Moskovich for administering the mixtures in all of the cases here reported, with the exception of but two.

The cases thus observed now number over fifty.

At first my efforts were directed toward verifying the facts first published by the physicians in Russia—Klikovitsch and others. Accordingly, I procured from a firm in this city a cylinder containing a mixture of twenty parts of oxygen and eighty parts of nitrogen monoxide, this being the mixture used by Paul Bert and others. The apparatus used was the same as employed for the administration of pure nitrous oxide gas; the S. S. White Inhaler No. 2 being used in connection with a seven-gallon rubber-bag reservoir. The first inhalation was taken by Dr. Moskovich himself, for a short time only, about two and a half minutes in all. After one minute he had lost sensation and consciousness; but there was no muscular relaxation. There was no trace of cyanosis, and subjectively no sensation of suffocation was experienced.

The next case was a successful one as far as the satisfactory completion of the operation was concerned: the incision and drainage of an axillary abscess, to which the patient, a young German girl, submitted without apparently feeling the least pain, although she retained consciousness all the time.

But the following three cases showed that the administration of this mixture produced excitation and incomplete anæsthesia, so that what still remained of the mixture was diluted with pure nitrogen monoxide in order to reduce the quantity of oxygen present to about half its original proportion, or to 10 per cent. With this mixture two successful operations were performed; the extraction of a foreign body in the hand of a woman twenty-four years of age, and the curetting of ulcerating tuberculous lymphatic glands of the neck in a man twenty-nine years of age. In both of these cases the patient was fully under the influence of the anæsthetic in from one to two minutes, and awoke at once at the removal of the inhaler. The anæsthetic was inhaled for four minutes without the least sign of cyanosis or asphyxia.

It was therefore believed that a mixture containing less of the oxygen would do better service; and a mixture containing 15 per cent. in volume of oxygen was prepared for me by the S. S. White Dental Co., of this city.[1]

This new mixture was administered twelve times. Dr. Moskovich kindly volunteered to inhale it, which he did for over five minutes consecutively. He took large inspirations and breathed naturally the entire time; the pulse was regular and full, not increased in frequency. There was no cyanosis or asphyxia. He remained conscious, however, or almost completely so, all the time. His subjective sensations were hammering and ringing in the ears; he could hear a loud voice, however, and feel a slight touch. The sensation of pain was greatly diminished but not entirely removed; anæsthesia was incomplete. A slight excitation was manifest to the by-standers; he followed our movements with his eyes, which were bright.

The cases treated with this mixture are the following:

Case I.—J. K., female, aged nineteen years; abscess of the palm. Duration of anæsthesia six and a half minutes. Anæsthesia not complete; reflex movements of the hand noticed during the incision. The patient subsequently stated that she had not felt much pain.

Case II.—B. W., female, aged seventeen years; abscess of the hand. Was partly unconscious; did not move the hand during the incisions. She subsequently said she had felt pain.

Case III.—B. K., female, aged eighteen years; abscess of the hand. Was unconscious in three-quarters of a minute. One incision, which was not felt, and not remembered. On awakening after two minutes a hysterical excitation was manifested, which soon passed over.

Case IV.—M. N., male, aged forty years; stricture of urethra. Patient of extreme neurasthenic condition, highly excited and nervous at taking gas. The excitement increased under influence of the mixture. After two minutes, mixture abandoned and pure nitrogen monoxide substituted. It was found impossible to bring the patient under its influence. Wild movements of the limbs, maniacal excitation, cries. Operation postponed to future date.

Case V.—N. M., male, aged fifteen years; complete luxation of forearm backward. The mixture administered for examination and replacement. In one and a half minutes, unconsciousness; no muscular rigidity or spasm, no reflex movements. Immediate revival on removal of inhaler. No remembrance of pain. On questioning, answered that he did not know where he had been. No after-effects.

This patient subsequently took the mixture twice more, and each time with similar excellent results. Massage and passive motion produced no sense of pain.

Case VI.—R. K., female, aged five years; large alveolar abscess. Took mixture for three minutes. Anæsthesia complete, but patient appeared not entirely unconscious. Incision. Immediate recovery.

Case VII.—F. S., female, aged eight years; abscesses of the hand

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[1] I take pleasure in acknowledging my indebtedness to the courtesy of this firm in supplying these mixtures, since by this means I was enabled to rely upon the accuracy of measurement and the good quality of the ingredients in each case.

and of the leg. Was given the mixture for six minutes. Consciousness and sensation had ceased after one minute; but slight reflex movements were noticed on incision through the skin.

CASE VIII.—L. E., male, aged three years; mastoid abscess. Unconscious after half a minute. Operation completed after three minutes. No sensation, but muscular rigidity of the extremities continued the entire time. Immediate recovery.

CASE IX.—H. W., male, aged twenty years; ingrowing toe-nail; extirpation of nail. Anæsthesia complete. On recovery, nausea and vomiting.

CASE X.—M. St., male, aged fifteen years; abscess of the jaw. The patient was apparently not fully under the influence of the anæsthetic when the incision of the abscess was commenced. Reflex movements and muscular spasm. Time of narcosis two minutes and two seconds. On recovery the patient stated he had not felt anything at all.

CASE XI.—A. S., male, aged twenty years; abscess at the back of the neck. Administration for two minutes only; anæsthesia complete, but muscular spasm and rigidity were present.

On reviewing these cases it became evident that this mixture is not satisfactory for surgical work, when administered in this manner. Only two cases of the eleven were satisfactory; in the others the muscular rigidity and spasm and the incomplete loss of consciousness interfered with the operation.

I therefore next procured a quantity of gas mixture from the same firm containing ninety parts by volume of nitrogen monoxide and ten parts of oxygen. With this mixture all further narcoses were conducted, and as far as the objectionable feature of the pure nitrogen monoxide anæsthesia—the asphyxia—is concerned, it was always avoided by the use of this mixture. No case presented any symptoms of cyanosis, the patient retaining the normal color of his skin throughout.

One of the first cases in which this new mixture was used was very successful.

CASE XII.—An adult man, suffering from an abscess of the neck, took the mixture and immediately fell into a peaceful sleep. Deep, normal respiratory movements continued and no excitement or muscular rigidity was manifested. The operation was completed in three minutes. The patient rapidly awoke on removal of the mask and had no consciousness of what had been done.

In the further cases treated with this mixture, however, the patients behaved very much as with the foregoing mixtures containing fifteen parts of oxygen to the hundred.

A state of semi-consciousness, combined with more or less muscular rigidity, manifested itself and interfered with the uninterrupted performance of the operative procedures.

It was made out, however, at this time that the chief impediment to the complete anæsthetization was the failure on the part of the patient to take deep inspirations. In the case of one or two patients (who had no beards) who took deep inspirations, the anæsthesia was much improved. But the natural excitability of many of the patients about to undergo a surgical operation is apt to prevent normal and deep respiration.[1]

As all these methods of administering mixtures of oxygen and nitrous monoxide gas had failed to give satisfaction, it occurred to me that by using pressure to force the gas mixture into the lungs of the patient, the amount inhaled might be increased and at the same time the tension of the nitrogen monoxide gas might be made greater.

This method is an entirely different one from that used by Paul Bert, who placed the patient in an entire atmosphere of greater tension, but did not influence the respiration in any way.

If, however, gas is administered under pressure, the mode of respiration is entirely changed. It approximates more closely to the artificial respiration which we have occasion to observe in our physiological laboratories; but with this difference, that the pressure in our case is constant, while there it is intermittent; moreover, it is not great enough to interfere with the natural expiration.

The practical question presenting itself was the construction of a proper apparatus, which should be readily portable and should permit of an exercise of pressure upon the gas reservoir that could be varied as desired.

The difficulties attending the hermetical connection between the mouth and nose of the patient and the reservoir bag were met by using the S. S. White Gas-inhaler No. 2, which in adults can be held in place so firmly by the administrator of the mixture that no air has access alongside of the mask.

In two categories of cases, however, this adaptation of the inhaler is interfered with. First, in children, for the reason that the mask is too large and admits air below the chin. If it were considered necessary to give the mixture to children under pressure, special inhalers of smaller size would have to be used. But in the case of children I have found that the mixture works quite sufficiently well without additional pressure, so that I have not as yet had such an inhaler constructed. Secondly, in cases where the patient has a large beard, it is difficult to prevent the entrance of air alongside of the inhaler. For this reason the majority of cases, where the mixture was used for anæsthetizing such patients, were failures.

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[1] In one case the attempt was made to use morphine subcutaneously in order to counteract the nervousness evidenced by the patient. But this endeavor proved a complete failure. The patient, a man, twenty years of age, was to have a toe-nail extirpated. He was of a highly nervous organization and excitable temperament. It was found impossible to get him under the influence of the mixture, and, therefore, pure nitrogen monoxide was substituted. But this had no more effect upon the patient than the mixture. There was unconsciousness, but apparently no anæsthesia, no insensibility. At each attempt to use the knife the patient would remonstrate, and move the lower extremities. The operation was finally completed, but on recovery the patient vomited, and appeared prostrated for some time. He said he had suffered much pain, but did not know where he was.

The amount of pressure necessary to induce anæsthesia is a question of some practical interest. According to Paul Bert's theory the tension with which the mixture is administered should bear the same proportion to the atmospheric pressure as the mixture bears to the nitrogen monoxide in the mixture. Thus, if we use a 10 per cent. mixture of oxygen and nitrogen monoxide, it will be sufficient to increase the pressure with which it is administered one-tenth of an atmosphere.[1]

In practice I have not as yet had opportunity to use so great a pressure—partly owing to the delicate construction of the reservoir bag used and partly owing to the arrangement of the mica valve in the inhaler used. The great majority of administrations of the mixture were given with the use of two simple boards of white wood, about two feet square and hinged together. Between these the rubber bag containing the mixture was placed, so that the gas was forced out into the inhaler at a pressure of about three-fourths of an inch of water on an average, this corresponding to a pressure upon the bag of three pounds, and when the gas was nearly consumed the bag was again filled from the cylinder *a tergo.*

Sometimes this pressure was employed from the commencement of the anæsthesia; but more generally the pressure was not added until the patient had inhaled the mixture for a minute or less and was considered under its influence. Then the weight of the upper board was brought to bear upon the bag.

The evident objection to this method of employing pressure is the following. When the two hinged boards approach each other the pressure upon the gas in the bag is increased, and when the bag is full and the boards become more separated in consequence, the pressure is diminished. The tension with which the gas escapes into the inhaler is consequently not equable. I have, therefore, of late contrived another simple arrangement of the two boards, by which they should remain always parallel to each other and thus render the pressure more equable.

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[1] To state the problem more correctly, and since the volume of a gas is inversely proportional to the pressure, we may adduce the following proportion:

9 vol. : 10 vol. : : 1 atm. : 1.111 atm.

The total pressure on the mixture should then be 1.111 atmospheres; of this 1 atmosphere will be due to the nitrogen monoxide and 0.111 atm. to the oxygen. Expressed in millimetres of quicksilver, the pressure of the nitrogen monoxide would be 760, and that of the oxygen 84.3.

The upper board is provided with four stout iron wire rods, about two feet long, and attached near the corners of the board after the manner of the legs of a table. These rods are unscrewed from their place for transportation. The rods pass through large holes in the corners of the lower board. The reservoir bag being placed between the two boards is thus exposed to a constant pressure amounting to five pounds and a half in the apparatus.

It will be seen that the administration of the mixture under pressure is a task requiring some skill and attention. In the first place, the mask requires to be held so firmly over the nose and mouth of the patient, that no air may enter alongside of the inflated rubber mounting. Secondly, the administrator should keep the reservoir-bag filled with the mixture during the entire time of the operation, so as not to cause any fluctuation of the tension under which the mixture is administered. At the same time he must watch the respiratory movements of the patient (as indicated by the valve in the inhaler), and the color of the patient's skin.

The first case in which the gas mixture was administered under pressure (in December, 1889), was a brilliant success.

CASE XIII.—The patient, a robust man of twenty years, suffering from a deep abscess of the finger, was given the mixture (containing 10 per cent. of oxygen), at first without pressure for three minutes. During this time he breathed naturally but retained consciousness, and could feel the prick of a pin as painful. Then moderate pressure was applied to the reservoir-bag (about two and a half pounds), and he immediately appeared to fall asleep. After one further minute there was complete atony, insensibility, absence of muscular spasm and rigidity, and absence of reflex movements. He recovered very rapidly after removal of the inhaler, and said he had felt nothing at the time of the operation.

Twenty-five further narcoses were conducted with the use of pressure-boards, and with the same mixture of ten parts of oxygen and ninety parts of nitrogen monoxide.

Many of these may be classed as brilliant successes, while others proved failures from one cause or another; and my attention was directed toward finding out, if possible, what occasioned the failures, so that they might be avoided.

I give the cases, as briefly as possible, commencing with the more successful ones.

CASE XIV.—R. S., female, aged thirty years; abscess of hand. Mixture given for fifteen seconds without pressure; then for three minutes with pressure. Patient completely anæsthetic and unconscious. Incision of abscess. Recovered rapidly.

CASE XV.—B. E., aged twenty years; two abscesses of the finger. Mixture given first for two seconds, then with pressure added for six minutes. Complete insensibility. Incision of abscesses.

Case XVI.—M. M., male, aged twenty years; abscess of hand. Mixture first given without pressure for twenty seconds, then with pressure. Complete anæsthesia and unconsciousness.

Case XVII.—M. S., male, aged seven years; foreign body under skin. Mixture given for twenty seconds without, then for one minute with pressure. Extraction of the body. Unconsciousness and anæsthesia complete.

Case XVIII.—N. S., male, aged thirty years; foreign body under nail. Mixture first given for fifteen seconds, then with pressure. Extraction of body. Anæsthesia and unconsciousness complete.

Case XIX.—M. C., female, aged twenty-five years; suppurative mastitis. Mixture administered without pressure for twenty seconds, then with pressure. Unconsciousness and anæsthesia well marked, but slight muscular rigidity in the extremities. Four incisions into the gland. On recovery from the anæsthetic the patient had a laughing spell, and was greatly delighted at the fact of the operation being completed.

Case XX.—The same patient was subsequently treated for other abscesses of the mammary gland, three incisions being made at this time. The anæsthetic was administered in the same way with the same good effect; but on recovery the patient wept and felt pain.

Case XXI.—L. S., female, aged nineteen years, in the eighth month of gestation; abscess of the hand. Mixture administered for one minute without, then for five minutes with pressure. Two incisions were made. Unconsciousness and anæsthesia well marked; but a little muscular rigidity was noticed.

Case XXII.—A. B., female, aged (?); suppurative lymphadenitis of neck. Mixture given for thirty seconds without pressure, then for ten minutes with pressure. Incision of abscesses.

Case XXIII.—M. G., male, aged eleven years; foreign body in gluteal region. Mixture given with pressure. Extraction of two large splinters of wood.

In both of these latter cases some slight cyanosis was observed, the supply of gas in the cylinder being nearly exhausted.

Case XXIV.—M. N., female, aged twenty years; tubercular lymphadenitis of neck. Mixture given first without, then with pressure. The patient lapsed into a peaceful sleep; unconsciousness and anæsthesia perfect; no reflex movements or muscular rigidity. Incision.

Case XXV.—L. H., male, aged sixteen years; incised wound of wrist. Mixture administered with pressure from the first. Anæsthesia induced in one-quarter of a minute; kept up for three minutes. Complete unconsciousness and insensibility to pain. Anæsthesia resembling a perfectly calm sleep. No cyanosis; no muscular rigidity. Disinfection and suture of the wound. Quick recovery on removal of inhaler.

There were two or three other cases, not recorded in my notes, which may be mentioned here, where the mixture was exhibited in cases operated upon by my colleague, Dr. Schapringer.

Case XXVI.—This one was an operation for the occlusion of a lachrymal fistula in a girl aged about six years. The anæsthesia proved perfectly satisfactory, the excision of the fistulous tract and the placing of the sutures being done with perfect ease during the unconsciousness and anæsthesia of the patient.

CASE XXVII.—Another operation was the extraction of a foreign body from the external auditory meatus in an adult man, the anæsthetic being administered in the sitting posture, and giving perfect satisfaction. The patient neither moved nor manifested signs of insensibility during the operation; although on questioning afterward he stated he had felt everything.

There were also some four further cases, of which, however, the notes have been lost.

Besides these successful cases of anæsthesia by this method of administering the mixture under pressure, there are several cases in which the results were less satisfactory.

CASE XXVIII.—L. G., female, aged six years; deep abscess of the neck, probably tubercular in character. Mixture administered without pressure for twenty seconds, then with pressure for four or five minutes in all. Incision and evacuation of abscess. The patient manifested a little excitement, breathed rapidly, and showed some cyanosis. (This was the residue of gas in the cylinder.)

CASE XXIX.—Adult female; ingrowing toe-nail. Mixture administered for five minutes, during which time the operation for extirpation of the nail proceeded satisfactorily, when clonic movements of the extremities and manifestations of excitation set in. The operation was successfully concluded, and although consciousness was absent, the movements suggested the sensation of pain.

CASE XXX.—A. W., male, aged eighteen years; severe contusion of the elbow. Mixture administered at first for fifteen seconds without, then for three minutes with pressure, for the purpose of using massage and passive motion. No pain was experienced, but slight tonic spasm was manifest in the muscles of the arm during the anæsthesia.

CASE XXXI.—V. P., female, aged twenty-two years, of very excitable disposition; suppurative axillary lymphadenitis. The mixture administered for two minutes and forty seconds under pressure before operation; then for three minutes and twenty seconds, or for six minutes in all. Incision and drainage of the abscess. Loss of consciousness complete; no cyanosis; but muscular rigidity present all the time. On awakening the patient lapsed into a hysterical condition, screamed, and was much excited. Vomiting also occurred.

CASE XXXII.—L. J., female, aged twenty-four years; was present during the foregoing operation, and much excited and frightened in consequence; suppurating mastitis. Mixture administered with pressure for five minutes and ten seconds in all. Remained partly conscious; muscular rigidity marked. Substitution of pure nitrogen monoxide; but patient could not be brought entirely under its influence.

There are, furthermore, some cases in which the action of the mixture under pressure were entirely unsatisfactory.

CASE XXXIII.—Male, aged thirty years; fistula-in-ano. Mixture given first without, then with pressure; but the patient could not be got under its influence. Pure nitrogen monoxide was then substituted, but with no better result, and asphyxia occurring with convulsions, the operation was abandoned.

CASE XXXIV.—B. S., male, aged thirty-one years; abscess of the hand. Mixture given under pressure. Incision of abscess. On removal of the inhaler a brief period of excitation of a maniacal character ensued, during which the patient uttered loud cries, walked across the room, and seated himself in a chair. On questioning, he afterward stated he had felt much pain. This patient was of a highly nervous temperament, but very muscular and robust.

CASE XXXV.—Adult man, with large growth of beard; fistula-in-ano. Mixture given under pressure but failed in its effect. Pure nitrogen monoxide substituted; but even with this the patient could not be anæsthetized. Great muscular spasm supervened and the operation, consisting in actual cauterization of the fissure and removal of hæmorrhoidal cicatricial excrescences, could be completed only with difficulty.

CASE XXXVI.—In still another case, that of an Italian, aged eighteen years, the mixture as well as the nitrogen monoxide failed to have the desired anæsthetic effect, but no mention is made in my notes as to the cause of the failure.

In reviewing all these cases where the mixture of oxygen and nitrogen monoxide was given under pressure, we must first consider those cases in which the anæsthetic failed to act satisfactorily.

These cases may be arranged in four groups or categories.

The first group comprises those patients who manifest extreme nervousness and excitability of temperament before they are given the mixture. There appears to be some element in the mental condition of these patients which counteracts the sedative influence of the mixture.

We know that certain medicines act differently upon persons of different temperament and idiosyncrasies; and that pain is largely dependent for its subjective appreciation on the attention. So, in order that a mixture of oxygen and nitrogen monoxide should induce perfect anæsthesia, the patient should be at his ease and not in an excited or frightened state of mind.

In the case of a woman, who had taken the mixture with good anæsthetic effect a day or two before, the administration of the same mixture utterly failed, because she had been frightened by the screams of another woman while under an anæsthetic during an operation preceding hers.

Closely allied to this first group of patients is a second, comprising those patients that look forward to an operation about the genital organs or the rectum. I know not why it is that this class of patients should be more difficult to anæsthetize than others. I have often observed, however, that such patients take ether and chloroform far worse than patients expecting operations on other parts of their bodies; and I believe the fact that operations upon the rectum or the genital organs are more dreaded than those on other parts will explain the matter.

A third group comprises those patients who have a heavy growth of beard. This interferes with the close fitting of the inhaler to the face, and consequently air is admitted into the lungs along with the mixture. The patient cannot, therefore, be considered to breathe the mixture as it is prepared, and the desired effect is lost.

Perhaps it may be possible, by moistening the beard with water or in some other manner, to exclude atmospheric air in these cases.

A last group is represented by a number of persons, upon whom the mixture as well as the pure nitrogen monoxide has no sedative effect at all, or at any time, quite independently of their momentary mental condition. Every practitioner or dentist who has had occasion to use nitrogen monoxide in a large number of cases, has met with patients who cannot be brought under the influence of the gas at all. Generally they become more and more excited as the gas is inhaled by them, and acute maniacal attacks are sometimes observed, during which they utter howls and shrieks and make violent muscular exertions—oftentimes of an aggressive nature, and increased by restraint. Such conditions are comparatively rare, occurring in my own experience in about two per cent. of the cases, and always pass over rapidly without any detriment.

I ascribe the cause of failure in this group to habit. For I believe this condition stands in some relation to chronic alcoholism; and judging by the difficulty we experience in bringing patients used to drinking large quantities of alcohol under the influence of chloroform and ether, I suspect a similar cause in these cases.

We therefore find the field for the administration of mixtures of nitrogen monoxide and oxygen considerably narrowed down, and are obliged to rule out, as unsuitable, quite an appreciable percentage of all the cases we may be called upon to treat.

In the majority of cases, however, in young, healthy individuals and in females, the anæsthetic mixture when administered under pressure was found to work well and to be much superior to the pure nitrogen monoxide for surgical purposes. It induces a state resembling a quiet deep sleep, in which the respiration is slow and regular, the pulse regular and full and not much, if ever, increased in frequency. The blood-pressure is not increased; and insensibility to pain and unconsciousness go hand-in-hand.

It was my fortune to meet with a class of patients, as far as the foregoing observations are concerned, who were not sufficiently intelligent to observe their own feelings with any accuracy, or to inspire the confidence of others in their statements. It is one of the characteristic features of the nitrogen monoxide that while it induces unconsciousness to the surroundings it does not interfere with the activity of the memory and imagination.

The mixtures cause the patients under their influence to sleep, but also to dream, and more or less vividly—and some, on awakening are apt to mistake their dreams for reality. Under these conditions it is difficult to know whether, when a patient says he felt an incision, he actually has remembrance of pain felt at the time, or whether the pain still present in the wound on the rapid awakening of the patient is not mistaken for the pain of the operation. For this reason I think it advisable to continue the anæsthetic for some time after the operation is completed, especially when nerve-trunks have been severed.

This rapid recovery after administration of the mixture under pressure is not so marked as when no pressure is used; the longer time the pressure has been used, the more time is required for recovery. In any case, however, according to my own experience, the interval of time between the removal of the inhaler and the recovery of the patient is too brief to admit of the satisfactory use of the mixture, even with pressure, for the extraction of teeth. The pure nitrogen monoxide allows the dentist more time to work in, during the slower recovery of his patient out of his asphyxiated condition.

Some writers are fearful, lest by keeping the mixture of oxygen and nitrogen monoxide under pressure in the steel cylinders, a higher oxidation of the nitrogen should occur, and nitrogen dioxide or other poisonous compounds be produced. As far as my experience reaches, I have seen no occasion for any apprehension, although I have given this question special clinical attention.

The contents of the cylinders procured from the company mentioned above appeared to act equally well whether they had been freshly prepared or kept on hand or stored for some time.

Some variation was observed, however, between the action of the first of the mixture escaping from the cylinder and that of the last. On opening the cylinder for the first time, the gas mixture contains more oxygen than the rest of the gas.

The first bagful is therefore not used at all, while the last two or three bagfuls of a cylinder act much the same as pure nitrogen monoxide, and should be given without pressure. The appearance of cyanosis in a patient under the influence of the mixture is a sign that the supply is giving out.

The large cylinder, holding three hundred and twenty and more gallons of gas, proved more satisfactory than the small ones, holding but forty; although they are less convenient for transportation.

In conclusion, I may say, then, that we have in the ten per cent. mixture of oxygen and nitrogen monoxide, an anæsthetic which may be administered with perfect safety and for a sufficiently long time to permit of the circumspect performance of most minor operations, but one which may be characterized as a weak anæsthetic. For although it will plunge the average adult into a state resembling peaceful slumber, in which anæsthesia and unconsciousness are well marked, it cannot gain the victory over states of great nervous excitement or dread, or certain habits and idiosyncrasies.

The anæsthetic action of the mixture is attained by administering it under pressure; and its usefulness is properly limited to the sphere of minor surgery in such cases where other anæsthetics are contraindicated or not desired, or where the saving of time is of great importance.

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